# ECEN 150 Lab 10 – RC and RL Time Constants

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## Purposes: (46 points total)

- Experimentally demonstrate the time constants of RL and RC circuits.
- Learn to adjust oscilloscope measurements using the vertical and horizontal control knobs.
- Learn how to use the measurement cursors on oscilloscopes.

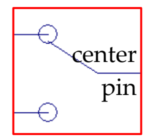
## Procedure:

**<u>Part 1. Measure & calculate RC charge and discharge time constants</u>**

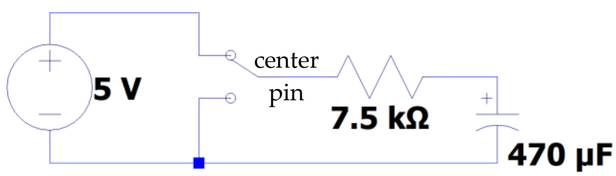
<u>Step 1: Construct the circuit.</u>

- Grab the following items:
  - A 470 µF capacitor
  - A 7.5 kΩ resistor
  - A slide switch (single pole, double throw)

- Construct the circuit shown below. A couple of wires may be necessary.
  - *Switch note*: the center pin on the switch is the center terminal shown on the schematic. If the switch is slid to the right, the center terminal connects to the right terminal. If slid to the left, the center connects to the left terminal.




  - *Capacitor note*: the polarity of electrolytic capacitors is indicated by a "- " sign or "0" printed on one side of the barrel. Arrows point to the low-voltage terminal.




<u>Step 2: Calculate the charge & discharge time constant and associated voltages.</u>

- *Calculate the time constant and the charging and decaying voltages after one time constant.*
  - The product of the values of a series resistor and capacitor, R*C, has units of seconds and is referred to as the "time constant", τ ("tau"): $\boxed{\tau = RC}$
  - **Calculate** the time constant $\tau = RC$ for the circuit you just built and **enter it** in the table on the next page. Be sure to **include units**. (Should be between 3-4 seconds).
  - The <u>voltage across</u> the capacitor in a series RC circuit will take t = τ seconds to:
    - Reach 63.2 % of its final value as it <u>charges</u> from 0%→100%
    - Decay to 36.8 % of the maximum value as it <u>discharges</u> from 100% → 0%

**Question 1**: What is the expected capacitor voltage when fully charged? _____5V_____ (2pt)

*Hint: The current through a capacitor under DC conditions is 0 A.

**Question 2**: What is 63.2 % of the final capacitor voltage? _____3.16V____ (2 points)

**Question 3**: What is 36.8 % of the final capacitor voltage? _____1.84V_____ (2 points)

Step 3: Measure the charge & discharge time constants.

- *Measure the RC charge time.*
  - Prep:
    - Use a voltmeter to measure the voltage across the capacitor.
    - Ensure the capacitor is fully discharged to begin (slide switch to 0 V to discharge).
  - Measure:
    - Slide the switch to 5 V while simultaneously starting a stopwatch (phone app).
    - When the voltage reaches the 63.2% voltage (Question 2), stop the watch.
  - Record: Repeat the above twice, recording your value both times in the table below. The times should be close to your calculated time constant value.
- *Measure the RC discharge time.*
  - Repeat the procedure above, but this time measuring the discharge time.
    - Ensure you begin with the capacitor charged to 5 V.
    - Slide the switch to 0 V and measure the time it takes to reach 36.8 % of the initial value (Question 3).
    - Do this twice and record the values in the table below. The times should be close to the calculated time constant.

| **Calculated RC time constant ($\tau = RC$)** | **Measured 0→63.2% time (charging)** | **Measured 100%→36.8% time (discharging)** |
|---|---|---|
| $\tau$ = 3.525 sec (2 points) | 1st try: 4.08 sec (2 points) | 1st try: 4.29 sec (2 points) |
| | 2nd try: 4.35 sec (2 points) | 2nd try: 4.36 sec (2 points) |

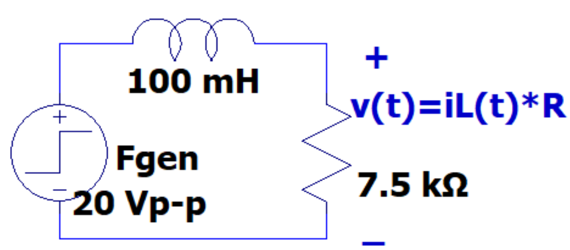
**Question 4:** What would happen to the charge & discharge times (i.e., the time constant) for this circuit if we doubled the series resistance? What if we halved the series resistance? (2 points)

If the series resistance was doubled, the charge and discharge times (the time constant) would also double. If the series resistance was halved, it would also be halved. This is because the time constant is R*C.

**Part 2. Measure & calculate RL charge and discharge time constants.**

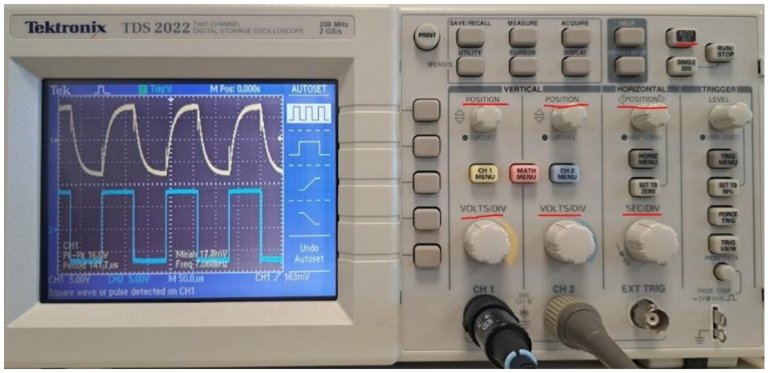
Step 1: Construct the circuit.

- Grab a 100 mH inductor. Construct the circuit below **using no wires**.
- Configure the function generator to produce a **square wave** of approximately 7 kHz with a peak-peak voltage of 20 V.
- Connect **Ch1** of the oscilloscope to measure the voltage across the resistor. (no wires)
- Connect **Ch2** of the oscilloscope to measure the function generator voltage delivered at the breadboard. (no wires)

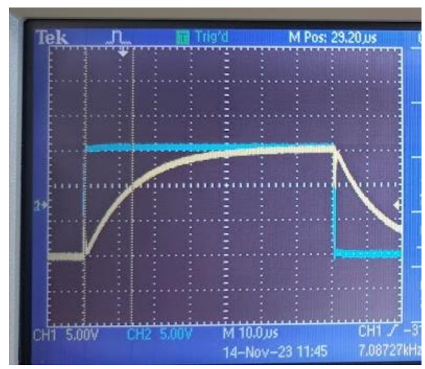


Step 2: Reposition the oscilloscope waveforms.

- With the oscilloscope and function generators on, hit "Auto set" on the oscilloscope. The machine will adjust the settings automatically to display both waveforms.
    - It should now look something like this:




- We want to reposition the two signals to appear on top of each other. To do this, adjust the "position" knobs under the "Vertical" panel for Ch1 and Ch2 as needed so that they overlap.
- We also want to zoom in horizontally so that we can better see just a single pulse. Adjust the "SEC/DIV" knob under the "Horizontal" panel such that you see only a single pulse, like shown here.




    - You might also need to adjust the "Horizontal" "Position" knob to move it left or right.
    - You should also adjust the "Volts/Div" knobs until the two waveforms take up as much of the screen as possible vertically.
    - *Ensure that you are actually receiving a 20 V square wave on Ch2! Adjust the function generator amplitude knob if needed. (*Note that the image shown here is only 15 V)

Step 3: Calculate the charging & discharging time constant and currents.

- *Calculate the time constant and the charging and decaying currents after one time constant.*
    - The "time constant", τ ("tau") of a series resistor & inductor is calculated as follows:

$$\boxed{\tau = L \,/\, R}$$

    - **Calculate** the time constant $\tau = L / R$ for the circuit you just built and **enter it** in the table on the next page. Be sure to **include units**. (Should be between 10-15 μs).
    - The current through the inductor in series RL circuit will take t = τ seconds to:
        - Reach 63.2 % of its final value as it charges from 0%→100%
        - Decay to 36.8 % of the maximum value as it discharges from 100% → 0%

**Question 5**: What is the expected maximum inductor current? ______2.7 mA______ (2 points)

*Hint: the voltage across an inductor in DC conditions is 0 V.

Oscilloscopes can only measure voltage, not current. Hence, we will indirectly measure the inductor current by measuring the voltage across the resistor since $V_R(t) = i_L(t)*R$.

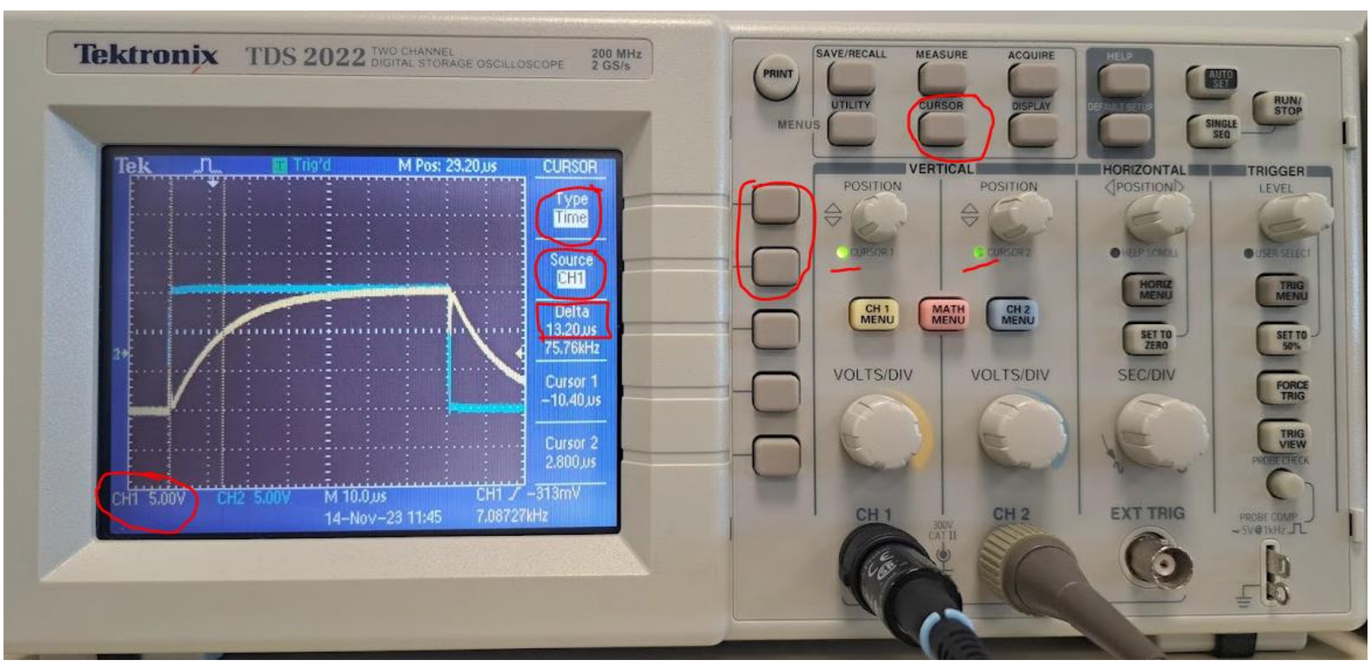
**Question 6**: What is the expected voltage across the resistor when $i_L(t)$ is at a max? ___20V______(2 pts)

**Question 7**: What should $V_R(t)$ be when $i_L(t)$ is at 63.2 % of the maximum? ______12.798V______ (2 pts)

**Question 8**: What should $V_R(t)$ be when $i_L(t)$ is at 36.8 % of the maximum? ____7.202V______ (2 pts)

Step 4: Measure the charge & discharge time constants.

- *Measure the RL charge time.*
  - Press the "Cursor" button near the top of the machine. This turns on two cursors which we will use for measurements. You should also see two green lights turn on under the vertical position knobs.
  - Press the button adjacent to the "Type" label on the screen until "Time" is selected since we will be conducting a time measurement.
  - Press the button adjacent to the "Source" label on the screen until "CH1" is selected since this is the channel measuring the resistor voltage.
  - The green lights under the two vertical position knobs indicates that these now control the cursors.
    - Turn the left position knob until the cursor aligns with the beginning of the blue input pulse.
    - Turn the right position knob until the cursor aligns with the 63.2% voltage you calculated in **Question 7**.
      - *You can estimate this by observing that each vertical "division" or grid square has a specific voltage. In the screenshot below, this is 5 V per division.
  - The label third from the top displayed on the right side of the screen is the "Delta" or difference between the two cursors. **Record** this value in the table below. It should be close to the calculated RL time constant.




| **Calculated RL time constant** ($\tau = L / R$) | **Measured 0→63.2% time (charging)** | **Measured 100%→36.8% time (discharging)** |
|---|---|---|

| | | |
|---|---|---|
| τ = ____13 us_____ (2 points) | τ = ____13.2 us___ (2 points) | τ = _____13.2 us______ (2 points) |

*Measure the RL discharge time.*

- Use the "Horizontal" knob to move the waveforms left/right such that you now see a full decay waveform (rather than the charging waveform).
- Adjust the cursors such that you measure the time between the pulse falling edge and the 36.8% voltage you calculated in **Question 8**. Record the value in the table on the previous page. It should match your calculated time constant.

*****Demo your oscilloscope measurement to the TA; then take Lab 10: Quiz 1*****

**Part 3. Conclusions statement.**

Write a brief conclusions statement that discusses all the original purposes of the lab. Please use complete sentences and correct grammar to express your thoughts on how you fulfilled the purposes of the lab:

Purposes (repeated):

- Experimentally demonstrate the time constants of RL and RC circuits.
- Learn to adjust oscilloscope measurements using the vertical and horizontal control knobs.
- Learn how to use the measurement cursors on oscilloscopes.

| |
|---|
| Conclusions (14 points):<br>In this lab we demonstrated the time constants of RL and RC circuits by building a circuit with an inductor and a circuit with a capacitor. We calculated the voltage which would be across each element at 63.2% of its final from charging and 36.8% of it discharging then measured using a voltmeter while timing to find the time it took to reach those voltages and that was the time constant. We learned how to adjust the oscilloscope measurements and the measurement cursers so that we could see the wave forms, time constants, and voltages on the oscilloscope. |

Congratulations, you have completed Lab!
You may now submit this document.